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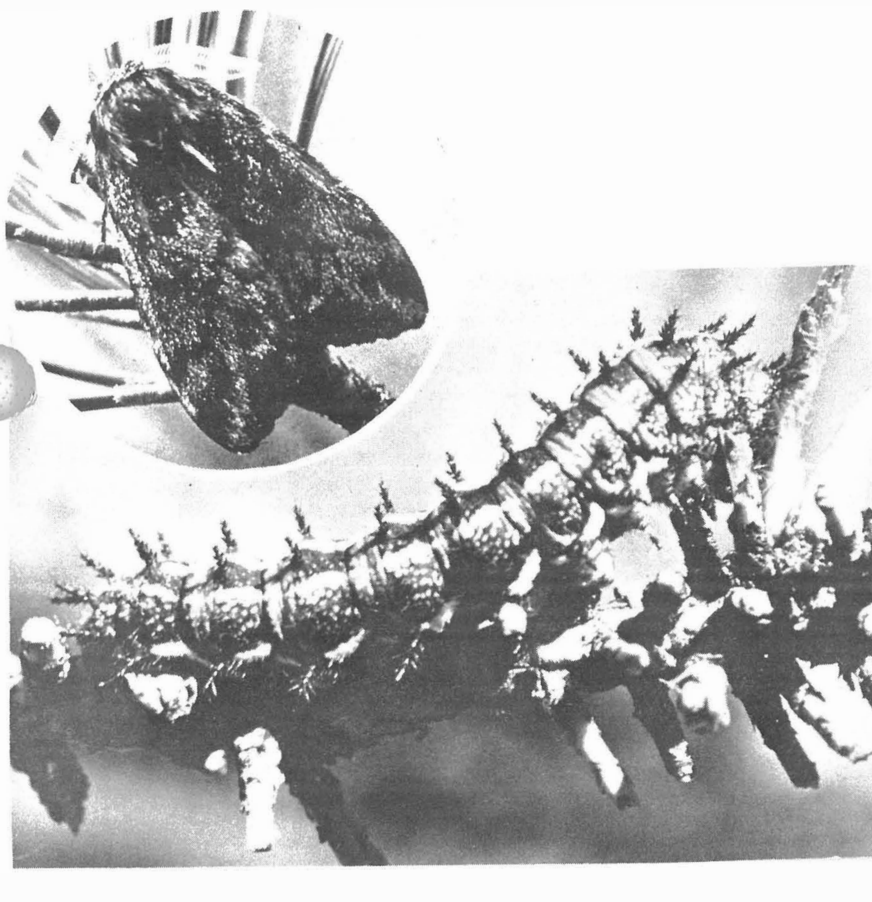
A Pilot Control Project to Evaluate Acephate for Control of Pandora Moth, *Coloradia Pandora Blake*, (Lepidoptera:Saturniidae), Jacob Lake, Arizona, 1981

North Kaibab Ranger District, Kaibab National Forest



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A PILOT CONTROL PROJECT TO EVALUATE ACEPHATE FOR CONTROL OF PANDORA MOTH, COLORADIA PANDORA BLAKE (LEPIDOPTERA:SATURNIIDAE), JACOB LAKE, ARIZONA, 1981

North Kaibab Ranger District
Kaibab National Forest
Arizona

by

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July 1982

Forest Pest Management
State and Private Forestry
Southwestern Region, USDA Forest Service
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Abstract

A pilot project was conducted on the Kaibab National Forest in Arizona to determine the effects of acephate on pandora moth, Coloradia pandora Blake, on ponderosa pine. Acephate was aerially applied at the rate of 1 pound acephate per gallon of water (0.75 pound active ingredient) per acre. There were five treatment blocks and three untreated (check) blocks. Each block had 15 three-tree sample clusters. Samples were taken 48 hours prior to treatment and 5 and 15 days following treatment to determine changes in larval population. A defoliation rating was taken on sample trees 40 days after treatment.

An average population reduction of 55.7 percent (unadjusted) was achieved on treatment blocks 3, 4, and 5, as compared to a 20.0 percent reduction on the untreated blocks. Blocks 1 and 2, which were subjected to heavy rain and snow following treatment, showed only a 21.1 percent reduction in population. Defoliation ratings and aerial photography showed the amount of defoliation on blocks 3, 4, and 5 averaged less than 25 percent, as compared to an average defoliation rate of 26 to 50 percent on the untreated blocks. Blocks 1 and 2 were severely defoliated.

Acephate, aerially applied at 0.75 pound active ingredient per acre, was shown to provide adequate foliage protection and it is recommended for operational use. However, acephate should not be applied if precipitation is likely within 6 days following treatment.

Acknowledgments

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14. Bob Young, USDA Forest Service, Forest Pest Management/ Methods Application Group, Davis, California.

Contents

Introduction

The pandora moth, Coloradia pandora Blake, is a periodic defoliator of pine forests in the western United States. The earliest recorded outbreak was on the Klamath Indian Reservation, Oregon, shortly before 1893. Earlier unrecorded outbreaks were indicated by the familiarity of Indian tribes in the Klamath area with this insect as a source of food. In parts of the West, outbreaks have occurred at about 20- to 30-year intervals and have lasted as long as 6 to 8 years (Carolin and Knopf 1968).

There have been no recorded pandora moth outbreaks on the Kaibab National Forest in the past, although moths were collected near Jacob Lake, Arizona, around 1941 (Wygant 1941). The current outbreak was first noticed in August 1978 near Jacob Lake by a private citizen (L. K. Sanders, personal communication). During 1979, pandora moth larvae defoliated 5,120 acres of ponderosa pine. The heaviest defoliation occurred 2 miles west of Jacob Lake, with 2,688 acres of complete defoliation and 2,432 acres of moderate defoliation. Light larval feeding was also noted on several thousand additional acres. Egg mass evaluations in November 1980 predicted defoliation in 1981 could be at least double that in 1979 (Parker 1980). Subsequent aerial detection surveys conducted July 29 through August 4, 1981, showed the area of visible defoliation covered approximately 19,000 acres.

Several issues and concerns were raised by the outbreak: (1) The adverse impact of the insect on the campground and tourist businesses at Jacob Lake; (2) temporary reduction in the visual quality of the forest around the high-use recreational site at Jacob Lake; (3) the potential local, short-term adverse effects of the defoliation on the Kaibab squirrel and other wildlife species; and (4) growth loss in defoliated pine stands and the possibility of tree mortality if a drought or bark beetle outbreak should occur simultaneously with heavy defoliation.

Since this insect occurs so infrequently, no pest management methods have been developed, and opportunities to test direct suppression methods have been limited. Thus, no chemical or biological agent has been registered for use against this insect. Preliminary work in the fall of 1980 indicated acephate appeared to be the most effective and environmentally acceptable of several insecticides screened (Hofacker et al. 1981).

This project was conducted by Forest Pest Management in the Southwestern Region, in cooperation with the Kaibab National Forest, to obtain the information needed on the

efficacy of acephate treatment for direct suppression. If effective, it could be implemented in 1983, should the outbreak continue. Personnel from Forest Pest Management; Methods Application Group, Washington Office; Arizona State Land Department, Division of Forestry; Rocky Mountain Forest and Range Experiment Station; and Pacific Southwest Forest and Range Experiment Station provided assistance and conducted additional studies in conjunction with the project.

Objectives

The objectives of this project were to:

A. Evaluate the operational effectiveness (reduction of insect densities and prevention of defoliation) of an aerial application of acephate against the pandora moth on selected areas of the Kaibab National Forest.

B. Reduce the adverse impact of the insect on the visual and recreational quality of the area.

C. Reduce the adverse effects of defoliation on the Kaibab squirrel and other wildlife.

D. Reduce potential growth loss and tree susceptibility resulting from defoliation.

E. Identify any problems associated with the mixing, timing, formulation, and application of acephate for use on pandora moth under field conditions in the Southwest.

Description of Insecticide

Acephate[2] (Orthene forest spray[3]) is a broad-spectrum organophosphate insecticide which is readily degraded by plants and has shown excellent control of several forest defoliators and numerous agricultural insect pests. Preliminary screening tests of acephate in the fall of 1980 showed substantial pandora moth population reductions (Hofacker et al. 1981).

The spray was formulated by adding 100 pounds Orthene to 100 gallons of water and 1 pound Rhodamine B extra soluble dye. The application rate was 1 gallon formulation (0.75 pound active ingredient) per acre. Orthotrol, an antidrift agent, was to have been added to each mixture to reduce drift. However, the Orthotrol was never received and after consulting with a Chevron representative, it was decided to proceed without the antidrift agent.

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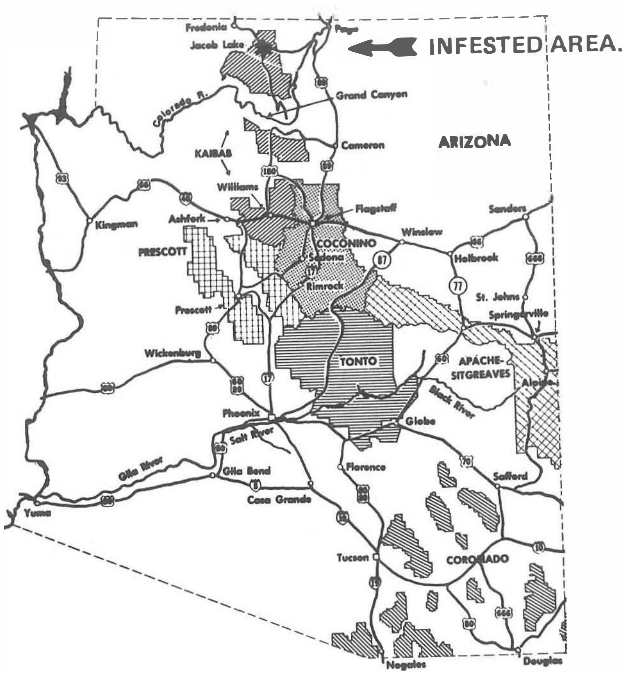
2 O, S-Dimethyl acetylphosphoramidothioate.
3 Chevron Chemical Company.

Project Design

DESCRIPTION OF PROJECT AREA

The project area was near Jacob Lake on the Kaibab National Forest of northern Arizona in Coconino County (fig. 1). The Kaibab Plateau is an essentially flat-topped ovoid 20 miles wide and 60 miles long with its long axis lying NNW-SSE. The topography is gently rolling and dissected by numerous, narrow canyons. Elevations range from 7,500 feet to 9,200 feet, with the elevation at Jacob Lake being 7,920 feet. The middle part of the plateau is generally higher and slopes downward in all directions. Ponderosa pine is the predominant tree species in the area and comprises 51 to 100 percent of the infested stands. Other tree species present include aspen, white fir, Douglas-fir, pinyon pine, Utah juniper, Rocky Mountain juniper, Gambel oak, and New Mexico locust.

Figure I. General location map.



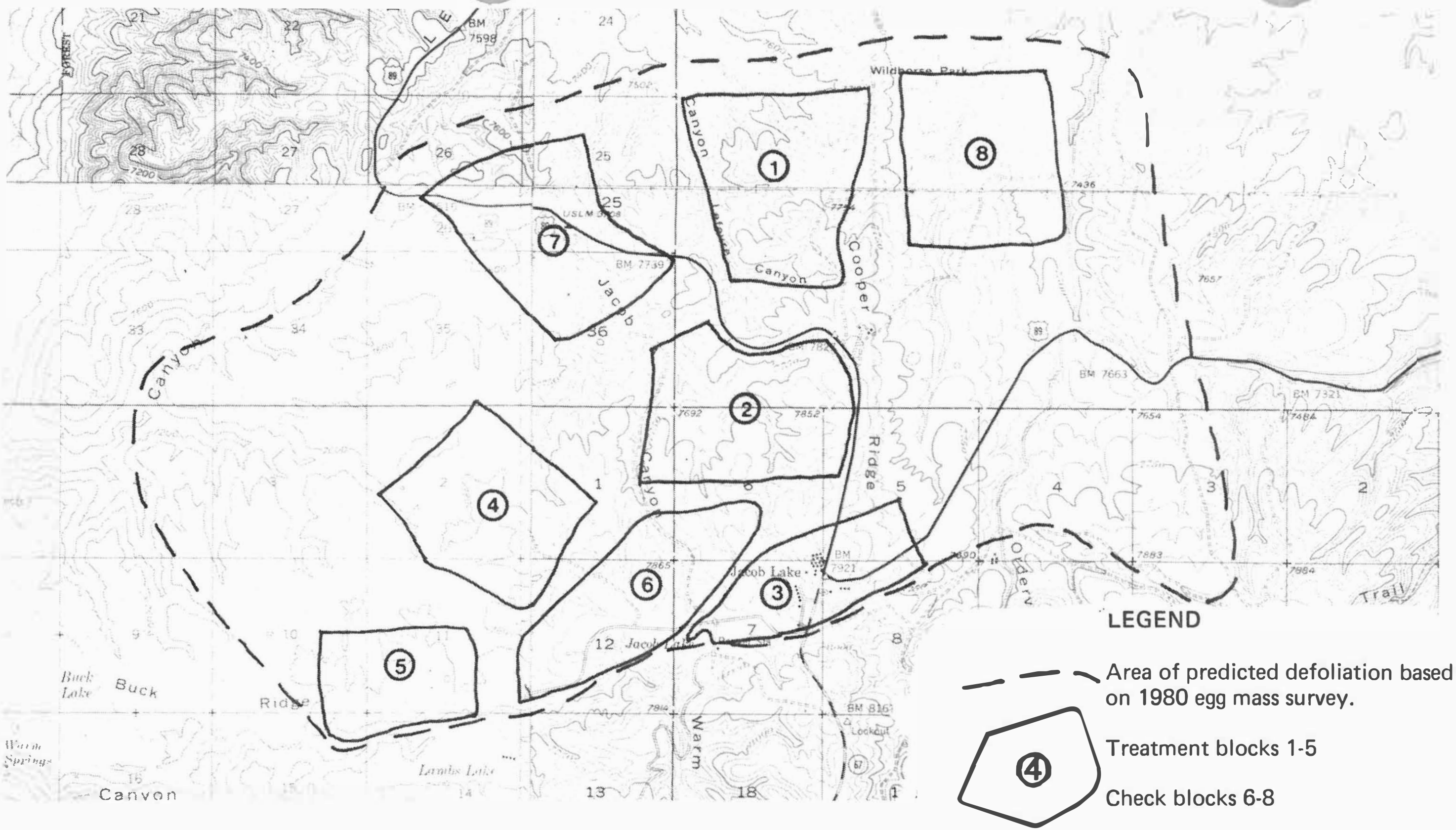
BLOCK SELECTION

Five treatment and three check blocks (fig. 2) were selected on the basis of: (1) Intensity of previous and expected defoliation (based on 1979 aerial surveys and 1980 egg mass and larval samples), (2) management objectives, (3) size--500 to 700 acres, (4) boundaries identifiable to natural terrain features or roads, and (5) accessibility.

Predicted defoliation for blocks 1, 3, 5, 6, and 8 is based on the 1980 egg mass survey conducted by Forest Pest Management personnel, Southwestern Region (Parker 1980). The following is a brief description of each block:

Block no.	Size	Defoliation intensity
1 (treatment)	700 acres	Predicted heavy
2 (treatment)	700 acres	Medium (in 1979)
3 (treatment)	500 acres	Predicted heavy
4 (treatment)	600 acres	Heavy (in 1979)
5 (treatment)	500 acres	Predicted heavy
6 (check)	500-700 acres	Predicted heavy
7 (check)	500-700 acres	Medium (in 1979)
8 (check)	500-700 acres	Predicted heavy

Figure 2. Location of infestation showing [illegible] of predicted defoliation, treatment blocks, and check blocks.



Application of Insecticide

AIRCRAFT

An Air Tractor, model 302, applied the spray mixture to the treatment blocks. This turbine-powered airplane is rated at 600 horsepower and, with a 385-gallon spray tank capacity, was well suited for spraying between 350 and 700 acres per hour (depending on ferry time) at a rate of 1 gallon per acre. It is owned and maintained by Valley Sprayer and Duster Service, Inc., Glendale, Arizona.

Operating Parameters

Aircraft speed - 150 miles per hour
Swath width - 150 feet
Boom pressure - 35 pounds per square inch gage
Release height - 20 feet above canopy
Nozzle type - Spraying Systems 1/8 GGA8W
Number nozzles - 33
Nozzle orientation - back 45° for blocks 4 and 5;
    straight down for blocks 1, 2, and 3
Application rate - 1 gallon total spray per acre

CALIBRATION AND CHARACTERIZATION

Calibration and characterization of the aircraft and spray system were conducted at the Kanab airport by Jack Barry and Patricia Kenney, Forest Pest Management/Methods Application Group.

MIXING AND HANDLING

Forest Pest Management provided the Orthene forest spray and Rhodamine B dye. The aerial spray contractor furnished all personnel and equipment necessary for mixing, handling, and loading the formulation. This equipment included a truck equipped with a Jet-A-Fuel tank for fueling the airplane, a 1,500-gallon water tank, a 400-gallon mixing tank, a flowmeter, strainers, and sufficient hose and pumps for transferring formulation into the aircraft.

The formulation was mixed one airplane load at a time (250-300 gallons) prior to each spray flight. A 40-minute turnaround from the time the airplane was loaded until it returned to the airport after spraying allowed sufficient time to mix each consecutive load. This method allowed the pilot to alter his loads as flying conditions changed and eliminated the necessity of storing or disposing of large amounts of formulation when spraying was unexpectedly discontinued due to high winds or precipitation.

All mixing took place at the Kanab airport in a fenced area, marked with restriction and warning signs. Forest Service personnel and a Chevron representative were present to record each formulation, obtain tank samples, and to observe and insure that proper mixing, loading, and safety practices were followed.

PESTICIDE STORAGE AND DISPOSAL

Prior to mixing, all pesticide and dye were stored in a designated pesticide storage building located at a Forest Service work center in Fredonia, Arizona, approximately 5 miles from the Kanab airport. Each "spray" morning, enough pesticide and dye to spray one to two blocks was transported, by pickup truck, to the mixing site. Unused pesticide and dye were returned to the storage facility after spraying was finished each day. Empty pesticide containers were disposed of at the Kanab sanitary landfill in the manner specified on the label.

SPRAY DEPOSIT ASSESSMENT

Spray deposition and droplet size were assessed by measuring the amount of spray material deposited on Kromekote cards placed in each treatment block. Rhodamine B dye, added to the spray formulation, made the spray deposit visible on the deposit cards. Prior to treatment, a 2- by 2-inch wooden stake was placed at the four cardinal directions under the drip line of each sample tree in each cluster. Each morning, prior to spraying, a plastic cardholder was attached to the top of each stake using double stick carpet tape, and a deposit card was inserted into the holder. Following application, the cards were allowed to dry, and then collected.

METEOROLOGY

Local weather forecasts were provided during spray operations on a daily basis by the Kaibab National Forest fire officer. On spray days, a weather observer was stationed at the Jacob Lake weather station (located in close proximity to all treatment blocks) to record temperatures, relative humidities, and windspeed/direction at 15-minute intervals from 4:45 a.m. until spray operations had ceased. This information was transmitted to the aerial observer which allowed him to terminate spraying when windspeed exceeded 6 miles per hour and/or temperature exceeds 70° F.

Weather conditions during the first day of spraying (May 13) were ideal, allowing treatment of blocks 4 and 5 as planned. On the second spray day, good weather conditions held during treatment of block 3, but increased windspeeds postponed the treatment of block 2 until the following day. Windspeeds averaged about 6 miles per hour during the first two loads on block 2, but by the third (final) load, they had increased to 12 miles per hour, forcing the postponed treatment of block 1.

Treatment of block 2 was complete at 7 a.m. Rain began falling at 2:30 p.m. and, within 2 hours, turned to a heavy, wet snow which lasted for nearly 24 hours, resulting in 1.32 inches of precipitation at Jacob Lake.

This adverse weather postponed treatment of block 1 until May 19. Rain and snow fell again on May 20, resulting in another .55 inches of precipitation. Local weather records taken during treatment are given in the appendix.

ORIENTATION OF SPRAY AIRCRAFT

An observation helicopter (Hiller J3-12E Soley for blocks 2 to 5, Bell 206B III for block 1) and aerial observer were used to direct the spray aircraft during the spray operations. On May 12, 1 day before actual spraying operations began, the aerial observer, spray airplane pilot, and the observation helicopter pilot flew over the blocks in the observation helicopter to become familiar with the terrain and to plan operation flight lines. Orange cloth markers (5 feet by 5 feet) were placed where block boundaries intersected roads. These orange markers were very useful to the aerial observer for orientation and block location. To aid in orientation, all blocks were marked on color resource photography (scale 1:15,840). As spraying progressed, each spray swath was marked onto the aerial photography.

Entomological Plan

CLUSTER PLOTS

Fifteen cluster plots, with three trees in each cluster, were established within each block and used as the basic sampling unit. Clusters were located throughout each block according to ease of access and were at least 2 chains from roads or block boundaries. Each cluster was mapped to facilitate relocation, and all sample trees were flagged and tagged with unique identification numbers.

An additional three sample trees were flagged at each cluster plot so various combinations of sample trees could be studied to: (1) Determine the sources of significant variation in larval counts, (2) compare the relative precision of each sampling design, and (3) determine the most efficient sampling design for future projects (Schmid et al. 1982).

SAMPLE TREES

Criteria for the selection of the sample trees were: (1) Ponderosa pine, 25 to 80 feet tall, (2) open grown as possible, and (3) sufficient foliage for three (2-branch) samples.

LARVAL PRESPRAY AND POSTSPRAY DATA COLLECTION

The basic unit of measurement was the number of larvae per branch. Two branches, ranging from 30 to 70 cm in length, were cut from opposite sides of each sample tree. Larval populations were sampled within 48 hours before treatment for each block, and at 5 and 15 days following treatment on blocks 3 through 7, inclusive. Blocks 1, 2, and 8 were sampled at 12 days following treatment, rather than at 5 and 15 days, due to heavy rain and snow.

The following information was recorded for each sample tree:

1. Date
2. Block number
3. Cluster number
4. Tree number
5. Branch number
6. Branch length
7. Number of pandora moth larvae per branch
8. Crew leader

FOLIAGE PROTECTION ASSESSMENT

Defoliation Rating

The amount of foliage saved due to treatment was measured by rating the percent defoliation of each sample tree during the period of peak defoliation, approximately 40 days after treatment (June 24 and 25). The visual ratings were categorized using the following classes:

0 - 0% defoliation
1 - 1-25% defoliation
2 - 26-50% defoliation
3 - 51-75% defoliation
4 - 76-99% defoliation
5 - 100% defoliation

An analysis of variance was used to determine significant differences in levels of defoliation between treatment and check blocks.

Aerial Photography

An aerial photography survey was conducted by the Methods Application Group and Forest Pest Management, Pacific Southwest Region, to evaluate foliage protection on blocks treated with acephate. Aerial photographs using Aerochrome IR-2443 film were taken of blocks 1, 2, 3, 5, and 8 at scales of 1:6,000 and 1:15,000 on May 7, prior to spraying, and again on June 26, after peak defoliation. A comparison was made to show visual differences in defoliation between treatment and check blocks, before and after treatment. Blocks 4, 6, and 7 were not photographed.

DATA ANALYSIS

Block means and standard errors were computed for each variable: larval densities prespray, 15-day postspray, and for the defoliation index. Mortality values were also computed.

Analysis of variance, analysis of covariance, and Duncan's new multiple range test were used to determine differences between treatment and check blocks for the following null hypotheses:

1. H_o: prespray larval densities are not significantly different.

2. H_o: 15-day postspray larval densities are not significantly different.

3. H_o: defoliation indexes are not significantly different.

SEQUENCE OF SAMPLING AND TREATMENT

The following chart shows the sampling and spray schedule for the project.

	TREATED BLOCKS					CHECK BLOCKS		
Date	1	2	3	4	5	6	7	8
May 12				P	P	P		
13		P	P	T	T		P	
14	P		T					P
15*		T						
16*								
18				5	5	5		
19	T		5				5	
28				15	15			
29			15			15		
30		15					15	
31**	15							15
June 24		DR	DR	DR	DR	DR		
25	DR						DR	DR

P = Prespray
T = Treatment
5 = 5-day
15 = 15-day
DR = Defoliation rating

* = Heavy precipitation
** = 12-day postsample was used as a 15-day post-sample.

Environmental Monitoring

The Pacific Southwest Forest and Range Experiment Station, in cooperation with the University of California at Davis, California, conducted environmental monitoring studies to determine:

1. Whether brain cholinesterase activities of passerine birds exposed to the spray were inhibited.

2. Residue levels of acephate and methamidophos (monitor, a deacylated product of acephate) in the brain and liver of some birds.

3. If the spray affected food habits of the birds.

Birds were collected in the morning by shooting with shotguns from both spray blocks and control blocks before the spray dates, on the day of treatment, and at intervals thereafter, up to 21 days following spray. Cholinesterase activity was determined by the Ellman technique as modified by Dieter and Ludke (Zinkl and Shea 1981). Residue levels were measured using a thermionic specific detector. Food habits were summarized by the occurrence and frequency of a particular family of insect in each bird's stomach.

Inform and Involve

The following actions were taken to insure public involvement and dissemination of information concerning this project:

Action	Responsibility	Date
1. Information posters were displayed at North Kaibab Ranger District, Jacob Lake Visitor Information Service (VIS) Center, and Grand Canyon National Park (North Rim).	Forest Pest Management (FPM)	June 1980
2. Mailed 1980 biological evaluation to interested individuals and organizations. These individuals were asked to help identify issues and concerns.	Kaibab National Forest Supervisor's Office (SO)	October 1980
3. Personal contact with 31 individuals and organizations.	Kaibab SO and North Kaibab Ranger District (NKRD)	October/ November 1980
4. Notification in Federal Register of intent to prepare an environmental impact statement (EIS).	SO and FPM	November 1980
5. Notification of draft EIS in Federal Register.	Environmental Protection Agency (EPA)	January 1981
6. News release concerning draft EIS.	Kaibab SO	January 1981
7. Notification of final EIS in Federal Register.	EPA	March 1981
8. Contacted concessionaires, private landowners, and Arizona Department of Transportation's (ADOT) Jacob Lake maintenance yard employees concerning proposed action. Area where ADOT employees live was not sprayed; however, they were contacted and notified that spraying would be done in the vicinity.	NKRD	April 1981

Action	Responsibility	Date
9. Obtained signed release from private landowner allowing spraying on his land.	NKRD	April 1981
10. Contacted concessionaires on proposed action. Concessionaires were advised to close their facilities the evening prior to spraying and during the spray application of unit 3. Concessionaires were notified as soon as possible about specific spray dates; they decided to remain open during the spray application and advised guests of the spray project. Guests and Inn employees were advised to stay indoors during the spray application in order to avoid breathing the spray mist.	NKRD and concessionaires	April 1981
11. Prepared a handout that was given to the public at the VIS and during spray project describing insect and project.	FPM and Office of Information	April 1981
12. Set up road blocks on 89A and 67 during spray application of units 2 and 3. Informed motorists of spray project and status of facilities at Jacob Lake.	NKRD and FPM	May 1981
13. Closed Forest Service campgrounds on day prior to spray application of unit 3. Closed VIS center during unit 3 spraying. Following spray application, facilities were opened after picnic tables were washed down.	NKRD	May 1981
14. Prepared news release on spray project results.	Kaibab SO	Summer 1981
15. Prepared final report.	FPM	June 1982

Safety Procedures

PROJECT SAFETY PLAN

A project safety plan was included in the appendix of the project work plan and issued to each person involved with the project. Objectives of the safety plan were:

1. Obtain involvement of all project employees in the safety program.

2. Establish open communications between the project employees, contractor employees, and the unit and project staff.

3. Incur no fatalities and no lost-time injuries.

4. Prevent accidents, both on and off the job.

5. Place management in the role of being responsible for safe and efficient accomplishment of program objectives.

Field crews were advised on proper safety procedures and issued necessary safety and first aid equipment.

PESTICIDE SAFETY PLAN

This plan covered the safe mixing and handling of acephate. It included label precautions, emergency information, a checklist for personnel working with the insecticide, procedure for cleaning up spills and/or leaks, emergency procedures, symptoms of poisoning, first aid instructions and antidotes, decontamination procedures, and disposal procedures.

AIRCRAFT OPERATIONS--AERIAL APPLICATION
OF CHEMICALS SAFETY PLAN

This plan covered all safety procedures regarding the aerial application, including persons working on or around the aircraft; aircraft maintenance, refueling, and operation; pilot safety; first aid and accident/incident reporting; and search and rescue. Also included was a list of emergency medical information and telephone numbers for the local hospital, helicopter paramedics, Kaibab National Forest dispatcher, District Ranger and acting District Ranger, Southwestern Region air officer, and local sheriff.

OBSERVATION HELICOPTER SAFETY PLAN

This plan incorporated general safety guidelines for developing, equipping, and manning helicopters and helispots used on this project. Included in this plan were safety procedures for personnel on, in, and around helicopters; helicopter maintenance, refueling, and operation; pilot safety; first aid and accident/incident reporting; search and rescue; and a list of emergency medical information.

All safety procedures were followed, resulting in no accidents or injuries during this project.

Organization and Responsibility

This pilot project was a cooperative effort involving the USDA Forest Service, Southwestern Region (Forest Pest Management (FPM)); Kaibab National Forest (KNF) and North Kaibab Ranger District (NKRD); Methods Application Group (MAG), Washington Office; the Pacific Southwest Forest and Range Experiment Station (PSW); the Rocky Mountain Forest and Range Experiment Station (RM); the Arizona State Land Department, Division of Forestry; and the University of California at Davis (UCD). The project organization is diagramed in figure 3. Specific assignments were as follows:

1. Design and review of project--all cooperators.

2. Information and involvement program--KNF.

3. Preparation of environmental impact statement--KNF and FPM.

4. Contracting of spray aircraft, chase helicopter, and insecticide mixing and loading operations--FPM.

5. Procurement of Orthene and dye--FPM.

6. Coordination of entomological and foliage protection surveys--FPM, MAG, RM, and Arizona Division of Forestry.

7. Meteorological support--NOAA and KNF.

8. Monitoring support--FPM, PSW, and UCD.

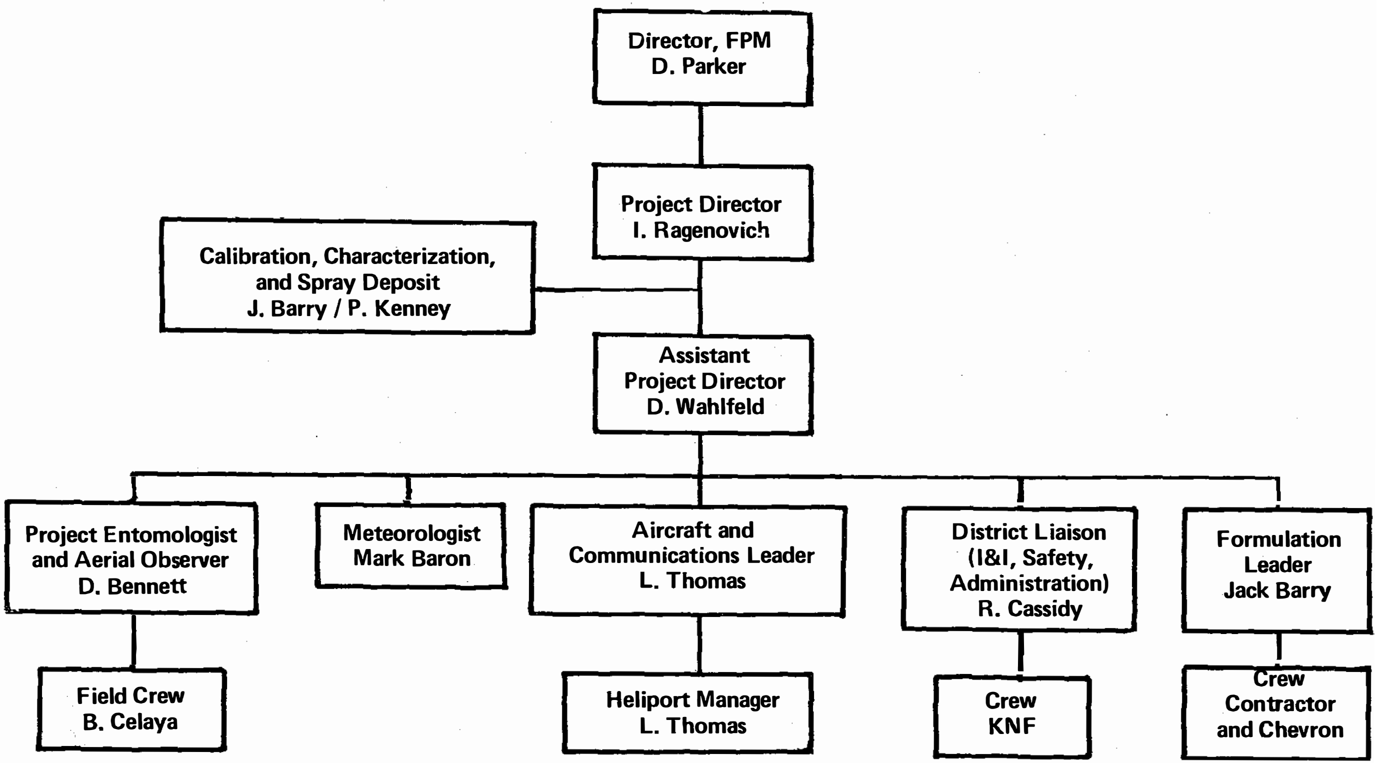
9. Spray deposit assessment--MAG.

10. Air operations and communications--NKRD.

11. Aircraft calibration and characterization--MAG.

12. Safety--NKRD.

Figure 3. Project organization chart.



Budget Summary

This project was funded by Forest Pest Management (FPM), Washington Office. Table 1 identifies actual expenditures including salaries, vehicle use, and supplies contributed by FPM, Southwestern Region; MAG; and the State of Arizona.

Table I. Project budget summary.

	Project budget	Contributed	TOTAL
Aircraft			
Fixed wing	$ 14,880		$ 14,880
Observation helicopter			
Project contract	2,381		2,381
Kaibab fire contract	2,184		2,184
Spray formulation			
Orthene forest spray	15,300		15,300
Rhodamine B dye	451		451
Vehicles	230	$ 1,603[1]	1,833
Equipment and supplies	1,531		1,531
Personnel salaries			
Administrative assistant		3,120	3,120
Director, FPM		1,664	1,664
Project director		1,352	1,352
Application specialist		640	640
Application technician		464	464
Project entomologist		1,392	1,392
Crewmembers		3,070	3,070
Administrative			
Overtime and hazard pay--FPM	2,802		2,802
Travel and per diem	4,116	2,041[1]	6,157
Services			
Computer analysis		500	500
Kaibab NF--includes salaries, overtime, travel, per diem, and vehicles for: Assistant project director, administrative assistant, inform and involve officer, meteorologist, aircraft communications leader, heliport manager, airport manager, airport crew, and district liaison	9,200		9,200
Environmental monitoring	19,000		19,000
Overhead	4,550		4,550
TOTAL	$ 76,625	$ 15,846	$ 92,471

[1] Includes vehicles contributed by FPM, Region 3; MAG; and Arizona State Land Department.

Results

POPULATION REDUCTION

The average number of larvae per branch before treatment and at 15 days after treatment, as well as percent larval mortality (unadjusted) at 15 days after treatment, is shown in table 2. Heavy precipitation precluded a 5-day postspray sample of blocks 1, 7, and 8, so a 5-day postspray analysis was not made.

Analysis of variance showed mean larval numbers between blocks were significantly different (0.5 level) at prespray and at 15-day postspray (table 3). Analysis of covariance, using prespray larval means (x) and 15-day postspray larval means (y), showed no significant difference in the mean larval numbers between treated and untreated blocks (table 3). However, if the blocks were regarded as three treatments: (1) Treatment followed by heavy precipitation (blocks 1 and 2); (2) treatment not followed by precipitation (blocks 3, 4, and 5); and (3) untreated (blocks 6, 7, and 8), rather than two treatments: (1) Treated (blocks 1 through 5) and (2) untreated (blocks 6 through 8), then analysis of covariance shows a significant difference between the mean larval numbers of the three groups (table 3). Further, Duncan's new multiple range test showed larval populations were significantly lower on blocks 3, 4, and 5 (treatment not followed by rain) than on the treated blocks followed by rain and the untreated blocks (table 3).

FOLIAGE PROTECTION ASSESSMENT

Defoliation Rates

Analysis of covariance using prespray larval densities (x variable) and 40-day postspray defoliation ratings (y variable) showed no significant difference between the treated and untreated blocks (table 3). However, if we again regard the blocks as three treatments: (1) treatment followed by heavy precipitation (blocks 1 and 2); (2) treatment not followed by precipitation (blocks 3, 4, and 5); and (3) untreated (blocks 6, 7, and 8), then analysis of covariance and Duncan's new multiple range test show defoliation ratings on the treated blocks not followed by precipitation are significantly lower than the treated blocks (table 3). Defoliation ratings for each block are shown in table 4.

Table 2. **Pandora moth larval populations and mortalities by (1) treatment followed by precipitation, (2) treatment not followed by precipitation, and (3) untreated blocks, North Kaibab Ranger District, Arizona, 1981.**

		Larval densities per branch					Percent mortality		
		Prespray		15-day postspray		15-day postspray adjusted by covariance			
	Block	Mean	S.E.[1]	Mean	S.E.	Mean	Unadjusted[2]	Abbott's adjusted[3]	Adjusted by covariance[4]
Treated with Precipitation	1	3.38	0.15	2.75	0.23		18.64		
	2	3.07	0.37	2.34	0.31		23.78		
	Combined	3.23	0.16	2.55	0.21	2.31	21.05	1.32	-2.67[5]
Treated without precipitation	3	2.98	0.25	1.50	0.22		49.66		
	4	1.15	0.11	.33	0.07		71.30		
	5	3.19	0.42	1.41	0.22		55.80		
	Combined	2.44	0.65	1.08	0.38	1.27	55.74	44.67	43.56
Untreated	6	3.19	0.30	2.44	0.30		23.51		
	7	2.53	0.25	2.39	0.26		5.53		
	8	2.84	0.47	2.01	0.40		29.23		
	Combined	2.85	0.19	2.28	0.14	2.25	20.00		

1 Standard errors for blocks are based on 15 clusters. Standard errors for the "combined" level are based on the block averages using 2 and 3 values, respectively.

2 Unadjusted mortality = $\left(1 - \frac{\text{postspray}}{\text{prespray}}\right) \times 100$

3 Abbott's adjusted mortality = $\left(1 - \left(\frac{\text{postspray treated}}{\text{prespray treated}}\right) \times \left(\frac{\text{prespray untreated}}{\text{postspray untreated}}\right)\right) \times 100$

4 Adjusted mortality by covariance = $\left(1 - \frac{\text{adjusted postspray treated}}{\text{adjusted postspray untreated}}\right) \times 100$

5 Mean larvae per branch at 15-day postspray sample was larger in treated blocks 1 and 2 than in untreated blocks 6, 7, and 8. However, difference was not significant (see table 3).

Table 3. Analysis of variance (anova) and analysis of covariance (ancov) to compare larval population means and defoliation rating on treated and untreated blocks.

Treatment	H_o:	F	F.05	Conclusion
Prespray	Prespray larval populations for treatment blocks (1, 2, 3, 4, & 5) and check blocks (6, 7, & 8) are equal.	(anova) 5.13	2.09	Treatment and check blocks were significantly different.
15-day postspray	Fifteen-day postspray larval populations for treatment blocks (1, 2, 3, 4, & 5) and check blocks (6, 7, & 8) are equal.	(ancov) 2.17	6.61	Treatment and check blocks were not significantly different.
	Fifteen-day postspray larval populations for treated blocks 1 and 2 (with precipitation), treated 3, 4, and 5 (without precipitation), and untreated blocks 6, 7, and 8 are equal.	(ancov) 15.07	6.94	Treatment and check blocks were significantly different. Blocks 3, 4, and 5 (treated without precipitation) were significantly different than blocks 1 and 2 (treated with precipitation) and blocks 6, 7, and 8 (untreated).[1] Blocks 1 and were not significantly different than blocks 6, 7, and 8.[1]
Defoliation rating	Forty-day postspray defoliation ratings for treatment blocks (1, 2, 3, 4, & 5) and check blocks (6, 7, & 8) are equal.	(ancov) 0.00	6.61	Treatment and check blocks were not significantly different.
	Forty-day postspray defoliation ratings for treated blocks 1 and 2 (with precipitation), treated blocks 3, 4, and 5 (without precipitation), and untreated blocks 6, 7, and 8 are equal.	(ancov) 15.90	6.94	Treatment and check blocks were significantly different. Blocks 3, 4, and 5 (treated without precipitation) were significantly different than blocks 1 and 2 (treated with precipitation) and blocks 6, 7, and 8 (untreated).[1] Blocks 1 and 2 were also significantly different than blocks blocks 6, 7, and 8.[1]

[1] Determined by analysis of covariance and Duncan's new multiple range test.

Aerial Photography

Figure 4 shows areas of relative defoliation as determined from interpretation of 1:15,000 scale color infrared aerial photographs taken at peak defoliation on June 26, 1981. About 75 percent of the untreated block 8 shows partial defoliation, while only 15 to 25 percent of treated blocks 3 and 5 show partial defoliation, with the remainder of each block undamaged. Partial to complete defoliation occurred over most of treated blocks 1 and 2.

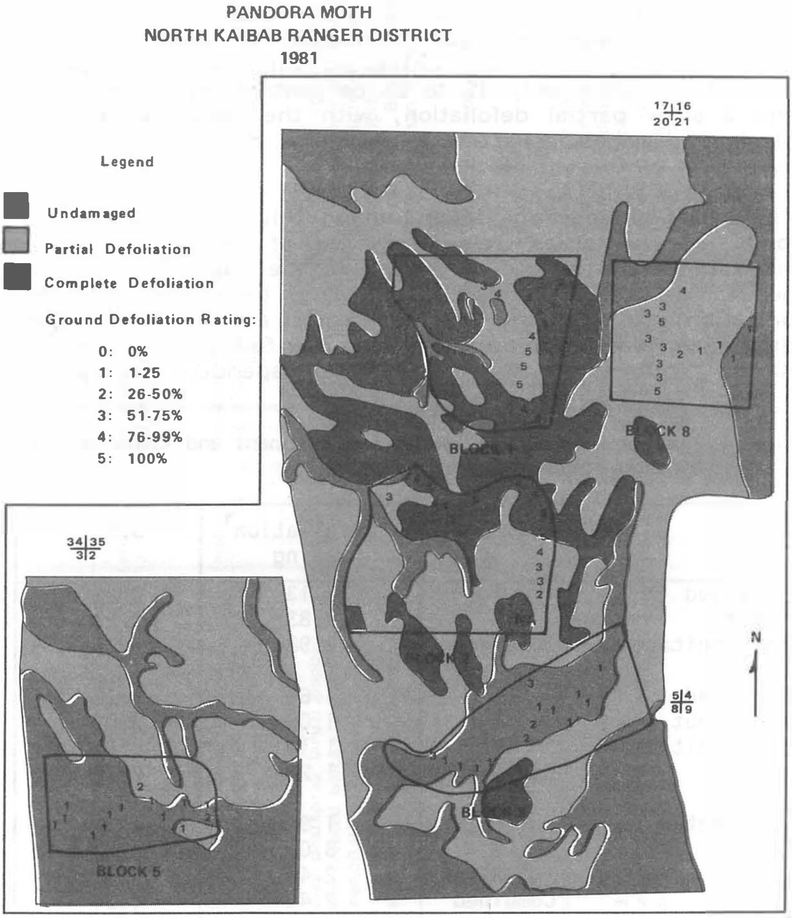
The aerial photographs taken during this project also reveal long, narrow areas relatively free of defoliation. Such areas, which often occurred even in the midst of untreated, heavily defoliated stands, were shown, by stereophotointerpretation, to be depressions, such as draws or small drainages, which may provide adequate foliage protection for Kaibab squirrels and other wildlife dependent on foliage.

Table 4. Average defoliation ratings for treatment and check blocks in pandora moth pilot project.

	Block	$\bar{x}$ Defoliation[1] rating	S.E.
Treated (with precipitation)	1	4.13	0.22
	2	3.83	0.21
	Combined	3.98	0.15
Treated (without precipitation)	3	1.60	0.19
	4	1.09	0.03
	5	1.14	0.06
	Combined	1.28	0.16
Untreated	6	1.91	0.14
	7	3.07	0.32
	8	2.46	0.31
	Combined	2.48	0.34

[1] Defoliation ratings were based on visual estimates of crown defoliation. Ratings represent the following percent defoliation: 0 = No visible defoliation; 1 = 1-25 percent; 2 = 26-50 percent; 3 = 51-75 percent; 4 = 76-99 percent; and 5 = 100 percent.

Figure 4. Areas of relative defoliation as determined by aerial photography and defoliation ratings determined from ground plots.



SPRAY DEPOSIT ASSESSMENT

Spray deposit cards were assessed by FPM/MAG using a quantimet image analyzer at the University of California at Davis. The drop diameters and recovery in gallons per acre were as expected and within the range experienced on similar projects (table 5). The number of drops per cm2 (3.67-7.12) is a little low, but not unexpected when evaporation is taken into consideration. The consistency of the data from one block to another reflects a high quality of application.

ENVIRONMENTAL MONITORING

The Pacific Southwest Forest and Range Experiment Station, in cooperation with the University of California at Davis, monitored the effects of acephate on six species of passerine birds. No individual birds of any species had depressed brain cholinesterase (ChE) activity on the day of spray. However, some birds did show depressed ChE activity at 2 days, 7 to 8 days, and 14 days postspray, indicating a biphasic ChE depression for some species (Zinkl and Shea 1981). Of the 124 birds collected following treatment, 5 had brain ChE activities depressed greater than 50 percent. According to Ludke (1975), such depressions are considered to be potentially lethal to birds exposed to organophosphates. However, other studies by Zinkl (1981) suggest that depression of 70 percent or greater is necessary to produce death in dark-eyed juncos (*Junco hyemalis*). No abnormal behavior of birds or dead birds were observed.

Table 5. Spray deposit data summary for pandora moth pilot project.

Drop Diameters (μm)	Spray Blocks				
	1	2	3	4	5
Volume median	287	292	274	301	281
Mass mean	294	297	280	311	287
Number medium	147	156	143	152	148
Number mean	162	171	156	167	162
Drops per cm^2	5.63	3.67	4.35	7.12	4.38
Recovery (gallon/acre)	0.27	0.20	0.18	0.37	0.20

Residue levels in brain and liver were highest in birds collected on the day of spray. Most of the birds collected for up to 8 days after the spray applications contained detectable levels (greater than 0.005 parts per million methamidophos, and greater than 0.05 parts per million acephate) of one or both of the compounds. However, the concentrations of the compounds were markedly lower at later dates and were not detectable at 21 days after treatment.

Regression analysis of the brain ChE activities and the brain residues did not show a correlation. In many instances, normal ChE activity was found in birds with high residue concentrations and similiarly low ChE activity was found in brains of many birds with low residue concentrations (table 6). These data suggest that another compound other than methamidophos or acephate, which presumably is a metabolite of one or both of the above compounds, is the bird brain ChE inhibitor (Zinkl and Shea 1982).

Table 7 is a summary of the food habits of the bird species monitored during this project. Qualitative analysis of this food habit data does not reveal any impact of the acephate application on the feeding behavior of these birds.

SPRAY COST PER ACRE

The cost per acre of this project, including expenditures contributed by cooperators, was $30.31.

Table 6. Range of methamidophos and acephate concentrations and number of birds with detectable residues in a forest sprayed with acephate at 0.75 pound active ingredient per acre.

Time[a]	Brain				Liver			
	Methamidophos		Acephate		Methamidophos		Acephate	
			Yellow-rumped warblers					
Prespray	ND[b]	(0/2)[c]	ND	(0/2)	ND	(0/2)	ND	(0/2)
Day 0	0.9 - 0.18[d]	(2/2)	0.77 - 1.30	(2/2)	0.07 - 0.64	(2/2)	1.86 - 4.90	(2/2)
2	ND - 0.10	(5/6)	ND - 2.10	(5/6)	0.07 - 0.19	(6/6)	0.27 - 2.00	(6/6)
3,4,5	ND - 0.15	(6/7)	0.03 - 1.04	(7/7)	ND - 0.06	(4/7)	0.10 - 1.30	(7/7)
7,8	ND - 0.03	(2/3)	ND - 0.17	(2/3)	ND - 0.03	(2/3)	0.13 - 0.38	(3/30)
14	ND	(1/4)	ND - 0.02	(2/4)	ND - 0.14	(1/4)	ND - 0.03	(1/4)
21	ND	(0.1)	ND	(0/4)	ND	(0/4)	ND	(0/4)
			Gray-headed Juncos					
Prespray	ND	(0/4)	ND	(0/4)	ND	(0/5)	ND	(0/5)
Day 0	0.16 - 0.37	(3/3)	1.20 - 3.10	(3/3)	0.04 - 0.26	(3/3)	0.25 - 4.40	(3/3)
2	0.10 - 0.17	(3/4)	0.40 - 5.75	(3/4)	ND - 0.06	(1/2)	ND - 0.88	(1/2)
3	ND	(0.2)	ND - 0.14	(1/2)	ND	(0/4)	TR - 0.04	(4/4)
7,8	ND - TR[b]	(1/2)	ND - 0.02	(1/2)	ND - 0.05	(3/4)	0.02 - 0.98	(4/4)

Table 6 (cont.). Range of methamidophos and acephate concentrations and number of birds with detectable residues in a forest sprayed with acephate at 0.75 pound active ingredient per acre.

Time[a/]	Brain				Liver			
	Methamidophos		Acephate		Methamidophos		Acephate	
14	ND - 0.11	(3/4)	ND - 0.30	(3/4)	ND - 0.01	(2/4)	0.01 - 0.05	(4/4)
21	ND	(0/2)	ND	(0/2)	ND	(0/2)	ND	(0/2)
			Grace's warblers					
Prespray	ND	(0/2)	ND	(0/2)	ND	(0/3)	ND	(0/3)
Day 0	0.02 - 0.10	(2/2)	0.50 - 7.70	(2/2)	0.04 - 0.10	(2/2)	2.60 - 3.60	(2/2)
2	0.03 - 0.08	(2/2)	0.40 - 0.90	(2/2)	0.01	(1/1)	0.04	(1/1)
3	ND - 0.05	(1/2)	ND - 0.62	(1/2)	ND - 0.02	(1/2)	0.13 - 0.42	(2/2)
4	0.04 - 0.06	(2/2)	0.02 - 0.16	(2/2)	0.02 - 0.03	(2/2)	0.07 - 0.24	(2/2)
8	0.02 - 0.04	(2/2)	0.06 - 0.06	(2/2)	ND - 0.03	(1/2)	ND - 0.06	(1/2)
14	ND	(0/2)	ND - 0.02	(1/2)	ND	(0/2)	ND - 0.02	(1/2)
			Western bluebirds					
Prespray	ND	(0/2)	ND	(0/2)	ND	(0/2)	ND	(0/2)
Day 0	0.14 - 0.16	(2/2)	0.30 - 0.33	(2/2)	0.02 - 0.08	(2/2)	0.07 - 0.16	(2/2)

Table 6 (cont.). Range of methamidophos and acephate concentrations and number of birds with detectable residues in a forest sprayed with acephate at 0.75 pound active ingredient per acre.

Time a/	Brain		Liver	
	Methamidophos	Acephate	Methamidophos	Acephate
2,3	ND - 0.02 (3/4)	ND - 0.15 (3/4)	ND - 0.03 (2/3)	0.01 - 0.48 (3/3)
4,5	ND - TR (1/3)	0.01 - 0.01 (3/3)	ND - 0.02 (2/3)	0.04 - 0.08 (3/3)
7,8	ND (0/2)	ND (0/2)		
14	ND (0/2)	ND (0/2)		
21	ND (0/2)	ND (0/2)	ND (0/2)	ND (0/2)
		Pygmy nuthatchs		
Prespray	ND (0/4)	ND (0/4)	ND (0/4)	ND (0/4)
Day 2	ND - 0.06 (1/2)	ND - 0.35 (1/2)	0.18 - 0.19 (2/2)	0.96 - 2.10 (2/2)
3	ND - 0.04 (2/4)	ND - 0.12 (2/4)	ND - 0.04 (2/4)	ND - 0.18 (2/4)

a/Time is the number of days after the spray, Day 0 birds were collected from 2 to 6 hours after application.
b/Abbreviations are: ND = not determined; TR = trace.
c/Numerator = number of birds with detectable residues; denominator = number of birds analyzed.
d/Lowest and highest residue concentration found on that day in parts per million (ppm).

Table 7. Occurrence of insect families and spiders in four species of birds during all sample periods.

	Yellow-rumped warbler	Grace's warbler	Western bluebird	Gray-headed Junco
Coleoptera				
Chrysomelidae				+
Curculionidae	+	++	++	++
Elateridae			+	
Scarabaeidae			+	
Scolytidae		+	+	+
Tenebrionidae			+	
Diptera				
Bibionidae	++	+	+	+
Mycetophilidae		+		+
Tephritidae		++	+	
Hemiptera				
Lygaeidae		+	+	+
Pentatomidae			+	
Homoptera				
Psyllidae		++		++
Hymenoptera				
Braconidae		++		++
Formicidae	+	+	++	++
Ichneumonidae		+	+	+
Torymidae		++		+
Xyelidae	+	++	+	+
Lepidoptera				
Unknown		++	++	++
Orthoptera				
Acrididae				+
Arachnida				
Araneida		++	+	

+ = occurred in 20 to 50 percent of stomachs examined
++ = occurred in 50 percent or more stomachs examined

Discussion

EFFICACY

The primary objective of this pilot control project was to evaluate the operational effectiveness (reduction of insect densities and preventing defoliation) of an aerial application of acephate (Orthene forest spray) at 0.75 pound active ingredient per acre. On treated blocks 3, 4, and 5, where adverse weather was not a factor, an overall population reduction of 55.7 percent (unadjusted) was achieved. However, heavy precipitation, following application, negated the effectiveness of treatment on blocks 1 and 2, where postspray larval populations and defoliation ratings were not significantly different from untreated blocks.

Other objectives of this project were associated with minimizing defoliation to reduce impact on visual and recreational quality, retain crown cover for suitable wildlife habitat, and reduce the possible stress and growth loss. By keeping the foliage losses on blocks 3, 4, and 5 to 25 percent or less, these objectives were achieved.

SAMPLING TECHNIQUES

In addition to the sampling scheme used for this project, Robert Young, Methods Application Group, and John Schmid, Rocky Mountain Forest and Range Experiment Station, tested a number of different sampling schemes for sampling pandora moth larval populations. Their work identified sources of variation and resulted in the following recommendations on sampling in regard to numbers of trees and branches per tree, and on the height and aspect from which samples should be taken on future pilot projects and biological evaluations (Schmid et al. 1982): (1) Precisely delineate infestation boundaries; (2) sample as many single-tree plots as possible; (3) use the one-tree, one-branch per tree design with the sample trees being systematically located throughout the infested area; (4) select samples from any aspect, but include 1 north sample in every 4 samples; (5) select branches 8 to 10 m above ground; and (6) select foliated, linear branches with a 40- to 60-cm tip which does not fork.

Recommendations

FUTURE SUPPRESSION USE

Although the larval population was reduced only 55.7 percent (unadjusted mortality) in this project, the objectives associated with foliage protection were achieved in those blocks not subjected to heavy precipitation immediately after spraying. Further population reductions and additional foliage protection might be expected under less severe climatic conditions. Therefore, until further field testing offers more effective treatments, we recommend that acephate (Orthene forest spray), aerially applied at 0.75 pound active ingredient per acre, be considered as a viable means of managing future pandora moth outbreaks, particularly in areas where foliage protection is of major concern. However, acephate should not be applied if precipitation is likely within 2 days following treatment.

INCLUDE ANTIDRIFT AGENT IN FORMULATION

Recent tests conducted by Chevron have shown that by adding an antidrift agent, such as Nalco-Trol or Orthotrol, to spray formulations containing acephate, as much as 22 percent more volume reaches the spray target (W. D. Cooper, personal communication). More information is needed to determine whether such increased volume recovery would result in increased insect mortality.

FALL FIELD TESTS

Results from field tests of five insecticides applied with an aerial application simulator in the fall of 1980 may have been influenced by the performance of the simulator (J. M. Schmid, personal communication). These results, combined with the relatively low mortality rates achieved on this acephate pilot project, indicate further field testing of acephate and additional chemicals is desirable. In addition, more information is needed regarding the amount of active ingredient needed on the foliage target to provide mortality, percent mortality by direct contact and by ingestion of contaminated foliage, and rain-fast properties of the tank mix. Therefore, we recommend studies be conducted to gather this additional information and to determine which, if any, pesticides might yield more satisfactory results in suppressing the current pandora moth infestation on the Kaibab National Forest, as well as any future outbreaks.

References

Carolin, Jr., V. M., and J. E. Knopf. 1968. The pandora moth. USDA Forest Serv., Forest Pest Leafl. 114. 7 pp.

Hofacker, T. H., C. E. Richmond, and J. M. Schmid. 1981. Insecticide testing against pandora moth larvae using simulated aerial application. Unpublished.

Ludke, J. L., et al. 1975. Cholinesterase (ChE) response and related mortality among birds fed ChE inhibiters. Arch. Environ. Contamin. Toxicol. Vol. 10, No. 1.

Parker, D. L. 1980. Pandora moth--North Kaibab Ranger District. USDA Forest Serv., letter biological evaluation. 6 pp.

Schmid, J. M., D. Bennett, R. W. Young, S. Mata, M. Andrews, and J. Mitchell. 1982. Sampling larval populations of the pandora moth. USDA Forest Serv. Res. Note. Unpublished.

Wygant, N. D. 1941. An infestation of the pandora moth in lodgepole pine in Colorado. J. Econ. Entomol. 34(5):697-702.

Zinkl, J. G., and P. J. Shea. 1981. Brain and serum cholinesterase, and brain and liver residues in birds and small mammals of a forest sprayed with 3/4 pound per acre of acephate. Unpublished.

Appendix

LOCAL WEATHER DATA, PANDORA PROJECT, JACOB LAKE, ARIZONA, 1981

DATE	TIME	TEMPERATURE				HUMIDITY	WIND		REMARKS
		Dry Bulb	Wet Bulb	Max	Min	At Obs	Speed	Dir	
5/13	0445	28				*	0	---	
	0500	30				*	0	---	
	0515					*	0	---	
	0530					*	0	---	
	0545					*	0	---	
	0600	28				*	0	---	
	0615	28				*	0	---	
	0630	32				*	0	---	
	0640	37	32			63	0	---	
	0700	43	35			49	.5	E	
	0715	47	36			37	2.4	NE	
	0730	48	36			33	1.6	NE	
	0750	52	39			33	1	NE	
	0800	53	39			30	6	SW	Wind switch
	0815	54	39			26	5	SW	Shutdown
5/14	0445	30		64	28	*	0	---	
	0510	28				*	0	---	
	0520	30	28			80	0	---	
	0535	30				*	0	---	
	0550	30				*	0	---	
	0600	30				*	0	---	
	0615	32				*	0	---	
	0630	35	31			68	1	SW	
	0645	47	37			42	5	SW	
	0650	49	38			39	7	SW	
	0700	50	38			35	7	SW	Shutdown
5/15	0435	43	37			61	4.7	SW	
	0500	42	36			61	6.0	SW	
	0510	43	37			61	6.3	SW	
	0520	42	37			66	4.1	SW	
	0535	42	37			66	4.5	SW	
	0545	42	37			66	5.8	SW	
	0610	41	36			66	4	SW	
	0630	43	37			61	6	SW	
	0640	45	38			57	10	SW	
	0650	45	38			57	12	SW	
	0715	46	39			57	12	SW	Shutdown
5/19	0440	44	33			33	4	SW	
	0500	43	33			37	4	S	
	0515	43	33			37	3	SW	
	0530	44	33			33	3	S	
	0545	44	33			33	4	S	
	0600	44	34			38	3	S	Winds gusty
	0615	44	34			38	2	SW	
	0630	44	34			38	2	SW	Shutdown

* No humidity reading--wet bulb frozen--probably 70 to 80 percent.